Technical Note N-1045

CATHODIC PROTECTION OF MOORING BUOYS AND CHAIN -- PART V. CONTINUED STUDIES WITH CABLES PROVIDING CONTINUITY

By

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ABSTRACT

An investigation was continued into the cathodic protection of fleet moorings, both the underwater portion of the buoy and the ground tackle. Sacrificial zinc anodes used on the ground tackle were specially cast on steel chain links so that they became an integral part of the ground tackle. The tight riser chain secured to the peg-top buoy had the required electrical continuity between chain links to permit the flow of current, but it was necessary to use a steel cable woven through the links of each of the ground legs and periodically joined to them to impart complete continuity between links.

The cathodic protection system was shown to impart complete protection from corrosion to both the underwater portion of the buoy and to the ground legs, whether the latter were on either a sandy or a muddy bottom. It is estimated that this system can provide such protection for a total of at least five years.

INTRODUCTION

Steel chain used to moor buoys and other floating structures in place is quite costly and subject to rapid corrosion in a hostile seawater environment. In previous studies[1-11] of coatings and cathodic protection for mooring buoys in San Diego Bay it was found that the riser chains on tight moorings with a cathodically protected buoy also received much of the cathodic protection. Because the chain is much more costly to purchase and maintain than the buoy, a study was initiated to cathodically protect both the chain and the buoy in a single system.

This is the fifth of a series of reports on the cathodic protection of fleet moorings. Part I[12] describes the initial field testing of cathodic protection as a means of reducing costs for maintaining fleet moorings for Naval Facilities Engineering Command field activities. The original system utilized sacrificial magnesium anodes connected through control heads designed to permit an automatic regulation of the level of electrical potential. When the control heads failed to function as designed, the magnesium anodes and their control heads were replaced by zinc anodes that require no external system of regulation. The zinc anodes performed satisfactorily but were present in insufficient numbers to provide the desired level of protection. Part II[13] describes a system using much larger zinc anodes cast on special chain links. This system provided complete protection to the riser chain, the ground ring assembly, and parts of the ground legs. The lack of complete protection to the entire ground tackle was attributed to poor electrical continuity between some of the chain links. Part III[14] describes the modification of the system with specially-cast zinc anodes in which a steel cable was woven through the links of each ground leg and periodically joined to them to provide electrical continuity. Part IV describes the testing of the latest modification. The present report, Part V of this series, concerns further testing of this modification in a location with a mud bottom.

PRESENT CATHODIC PROTECTION SYSTEM

The cathodic protection system presently being tested in San Diego Bay is shown schematically in Figure 1. A Mark II peg-top riser-chain mooring buoy was modified by building two sea chests into it on opposite sides below the water line. This permitted a sacrificial anode to be placed into each in a position where it would not be susceptible to abrasion or impact damage from vessels utilizing the mooring. Remote ground cables are electrically connected from each anode to the buoy shell at the opposite side in order to distribute the cathodic protection.

The ground tackle of the test mooring has a 20-foot riser-chain and four 225-foot ground legs (2½ shots of chain). Three special zinc anodes were placed on each ground leg, as shown in Figure 1, such that no point on the leg was further than 45 feet from an anode. One special anode, was also attached in the riser chain so that the ground ring assembly area (where all four legs are secured) which generally receives the most deterioration has plenty of protection. The anodes were joined to the chain with standard detachable links. As is the procedure followed by Public Works Center, San Diego, the chains (but not the anodes) were coated with coal tar (MIL-C-18480) by dipping in a tank of this material before the mooring was installed in San Diego Bay.

The zinc anodes (Figure 2) were specially prepared by casting SA-3 zinc alloy around 2½-inch thick steel links 35 inches in length. The zinc casting was of trapezoidal cross section, with a length of 1.8 feet and a total surface area of approximately 6.6 square feet. The weight of the entire anode was approximately 485 pounds.

The arrangement of the cathodic protection system showing methods of cable attachment is shown in Figure 3. Through each of the ground legs a single length of galvanized steel cable was loosely woven back and forth the entire length of each leg and joined to every sixth or seventh link. On two of the legs the joints were accomplished by silver-soldering and on the other two joining was accomplished with pipe clamps. Joining with pipe clamps had the advantages of being faster and not requiring the services of a welder. The clamps were snapped into position and then further tightened with a screw driver. One pipe clamp was secured in place by a diver at the time of a later inspection to demonstrate that securing the cable underwater presented no real difficulty.

As shown in Figure 3, Leg 1 (Upstream Coronado) was constructed of 2½-inch cast steel chain with a 3/4-inch galvanized steel cable clamped to it; Leg 2 (Downstream Coronado) was constructed of 2½-inch die lock chain with a 3/4-inch glavanized steel cable welded to it; Leg 3 (Downstream San Diego) was constructed of 2½-inch cast steel chain with a 3/4-inch galvanized steel cable clamped to it; and Leg 4 (Upstream San Diego) was constructed of 2½-inch die lock chain with a 3/4-inch glavanized steel cable welded to it. Thus, the 12 anodes on the ground legs were designed to protect 10 shots of chain (900 feet) on the four ground legs. The cables on each leg were terminated six links from the Jew's harp of each anchor, rather than at the A-link nearest the anchor as in the previous modification, to reduce current loss to the anchor. Thus, full protection of the chain was desired rather than partial protection of the anchor at the price of incomplete protection of the chain.

The initial installation shown in Figure 3 was located in an area of San Diego Bay that had a sandy, rocky bottom. Here it performed well for 13 months. At that time it became necessary to relocate the mooring because it was located in the area of construction of the new San Diego - Coronado bridge. This afforded the opportunity to expose the mooring under a different type of environment. A site with a muddy bottom and appreciably less tidal currents was chosen. Muddy bottoms are associated with anaerobic environments.

POTENTIAL PROFILES OF MOORING

Potential profiles of the cathodically protected mooring were made periodically after installation. The profiles of electrical potential imparted by the zinc anodes were made by a diver carrying two 50-foot leads from a portable meter read at topside. The instrument was read while the diver made electrical contact to the mooring chain with a steel pick joined to one lead and held a reference silver/silver chloride half-cell joined to the other lead about one foot from the point of contact. Readings were made about every 10 to 20 feet. During the 13 months at the location with the sandy, rock bottom, all readings were well above the desired minimum level of -850 mv, and all but two were above -900 mv. These two were at the end of one leg where some cathodic protection was being given to the anchor.

The first attempt at measuring a potential profile at the new site was made about four months after relocation. At that time the two San Diego legs were under about one foot of mud, and the two Coronado legs were under about two to three feet of mud. A rather strong wind and the erratic operation of one of the engines of the diving boat further complicated the measurement of potentials. As a result, only the partial potential profile listed in Table 1 was obtained. It was difficult to obtain precise readings because the diver could not maintain contact with the chain for a prolonged period of time. Two of the anodes buried on one of the legs in the mud were not located by the diver. All measurements were well above the desired minimum of -850 mv, and all except one were -900 mv or above.

About nine months after relocation of the cathodically protected mooring, another potential profile was measured. A new, more easily handled diving boat was used and there was no appreciable wind. All four ground legs were covered with about one foot of mud, and it was much easier to measure the potentials recorded in Table 2. Still one anode on Leg 4 was not located. All potentials measured were still well above -850 mv, but those on Leg 2 were noticeably lower than those on the other legs. This may have been due in part to sluggishness of the meter and the inability of the diver to maintain contact with the chain for an extended period of time. One of the anchors was receiving full protection from corrosion, one partial protection, and two no appreciable protection. It is interesting that the anchor noted to be receiving full protection after four months was receiving no protection after nine months.

The potential profile of the cathodically protected mooring was again measured 15 months after relocation. These measurements are recorded in Table 3. It was possible to measure potentials at all key points of the mooring. Again all of the measurements were well above the desired minimum of -850 mv. At this time Leg 1 had very slightly lower readings than the other three legs. Two of the anchors were receiving partial protection from corrosion and two were receiving no appreciable protection.

CONDITION OF MOORING

At the time of relocation, the mooring buoy and chain were in excellent condition. The mooring crew remarked that the chain looked as good as the day it was first installed. Not only was the corrosion of chain negligible, but the chain coating was in good condition. The anodes had a loose yellowish film of zinc oxidation products on them as a result of their production of electrical current, but there were no signs of passivation, such as was previously found by Peterson and Waldron[16] on zinc anodes in San Diego Bay. There was no marine fouling on the anodes, as zinc compounds are known to be toxic to marine organisms.

Eleven months after relocation of the cathodically protected mooring, the buoy was lifted from the water for the annual inspection specified in BUDOCKS Instruction 11153.4B. At that time the buoy was in excellent condition except for extensive marine borer damage to the lower wooden fender (Figure 4). There was very little corrosion above water (a few pinpoint rust spots) and none below. The riser chain showed no deterioration and the paint was still intact. A routine thickness measurement with a pair of calipers (Figure 5) revealed no reduction in chain thickness but a slight increase due to the thick paint. Both the buoy and the riser chain had medium to heavy marine fouling typical of other moorings in the area. Tunicates, barnacles, and green algae were the most typical organisms present. These were removed by high pressure hosing with seawater before the inspection.

A foot-square area below the water line of the buoy had been sandblasted to bare steel at the start of the test program[12] in order to give a better indication of the cathodic protection of exposed steel. At the latest inspection this area (Figure 6) was covered with fouling organisms and a black film but had no pitting or other signs of active corrosion.

The surfaces of the two anodes in the buoy sea chests were covered with a loose yellowish film, but under this film the zinc metal was bright and irregularly pitted (Figure 5) indicating satisfactory performance. More than half of the original zinc remained on each anode. The diver reported that the anodes on the ground legs were in a similar condition.

DISCUSSION

The cathodic protection system continues to provide full cathodic protection to the test mooring (except for the anchors) in the new location. The anaerobic conditions in the muddy bottom where the ground tackle is located did not cause passivation of the anodes. From the measurements of electrical potentials and the appearance and size of the anodes, the cathodic protection system gives every indication that it will continue to perform well for several years.

The profile of electrical potential changes with each measurement, but the chain and the underwater portion of the buoy continue to receive full protection. These changes are attributed to tightening and slackening of the chain by semidiurnal tides and by moored ships. On the ends of the ground legs where there is relatively little motion, the steel cable provides the necessary electrical continuity. Even the anchors occasionally receive cathodic protection despite an attempt to prevent this by terminating the cable six links from the Jew's harp of each anchor. These six links, of course, should receive protection in order to prevent severing the chain at this location. Past experience, however, has shown that chain corrosion occurs most extensively at the ground ring assembly (Figure 7), and ground legs are sometimes changed end-for-end in order to distribute metal losses. Anchor weight losses by corrosion are relatively small and have little effect on the holding power.

The soft coal tar coating on the chains was in relatively good condition although there was appreciable barnacle penetration, especially on the upper portion of the riser chain. Apparently, the cathodic protection prevented the extensive undercutting by rust that occurs on unprotected moorings. The good condition of the coating, in turn, greatly reduced the amount of current required to cathodically protect the steel.

A control mooring with the same buoy and chain protective coating systems as the test mooring but without cathodic protection was installed at the same time as the test mooring. The controlled mooring has long since been removed[14] (after 31 months of service) because of corrosion damage, especially at the ground ring assembly.

A comparison of maintenance costs for moorings with and without cathodic protection was previously reported.[14] Based on a five-year service life for a cathodic protection system for a fleet mooring and a ten-year life for an unprotected mooring, an annual savings of over $3600 was estimated for a cathodically protected mooring. From the present data and rising labor costs, it appears that this is a conservative figure.

In the Appendix is presented a cost analysis for rehabilitating four 7- and 8-legged fleet moorings. The overhaul portion of the costs for each mooring was estimated to break down to 30% for overhaul of the buoy and 70% for overhaul of the ground legs. The latter costs were higher because of the high labor costs in sandblasting the ground legs prior to their dip-coating with a coal tar paint. Removal and reinstallation comprised about 63% of the total costs, as compared to 34% for actual overhaul. Thus, annual maintenance costs would be less with a cathodic protection system, and the fleet mooring itself should have virtually an indefinite life with no downgrading to a lower rating and eventual scrapping.

FINDINGS

1. The presently designed cathodic protection system has provided complete protection from rusting to the underwater portion of the test

buoy and to its entire ground tackle (except the anchors) for fifteen months at the new location with a muddy bottom in San Diego Bay.

2. Anaerobic conditions on the muddy bottom have not resulted in anode passivation.

3. Electrical continuity necessary for the distribution of cathodic protection of the ground legs was provided by periodically joining a ground cable to them.

4. Both the silver-soldered and pipe-clamped joints of the cable to the chain were effective in maintaining electrical continuity.

5. The anodes seemed to have enough zinc remaining for at least 2 additional years of cathodic protection (a total of 5 years).

CONCLUSION

The present cathodic protection system can provide complete protection from corrosion to the ground tackle and underwater portion of a mooring buoy installed in an area with either a sandy or muddy bottom for at least five years. This system can result in considerable reduction in costs of maintaining fleet moorings.

RECOMMENDATION

It is recommended that a cathodic protection system of the present design be widely used throughout the Naval Shore Establishment. The logical first step in the implementation of this action is to install a number of cathodically protected moorings at different, selected locations in order to establish range of applicability and determine cost reduction and necessary maintenance procedures for areas other than San Diego.

ACKNOWLEDGMENT

Lieutenant Richard F. Heine, formerly of Public Works Center, San Diego, and currently Senior Activity Civil Engineer at Naval Training Center, San Diego, spent considerable time gathering the data presented in the Appendix. His extraordinarily diligent effort in this endeavor is gratefully appreciated.

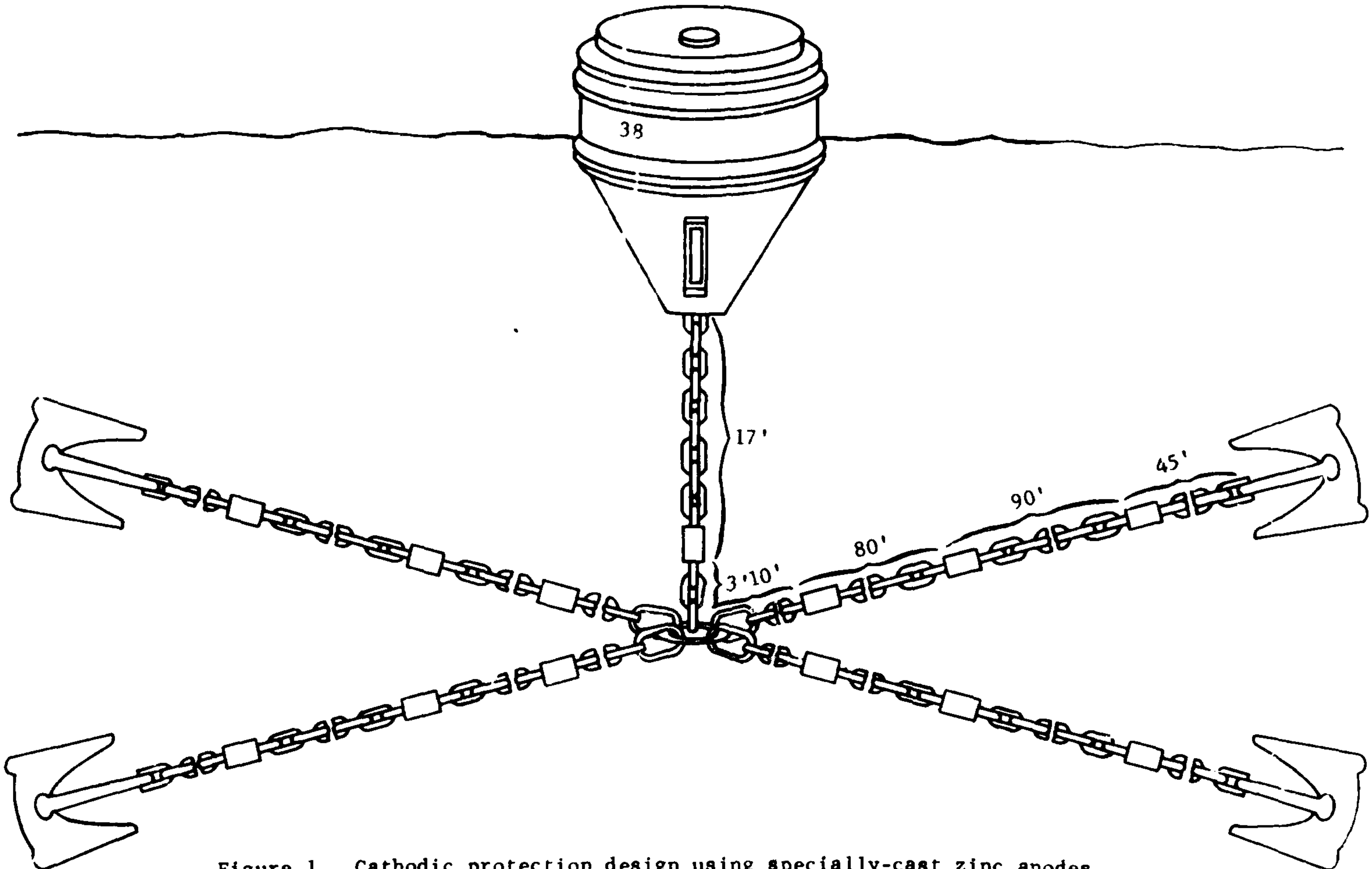

Figure 1. Cathodic protection design using specially-cast zinc anodes.

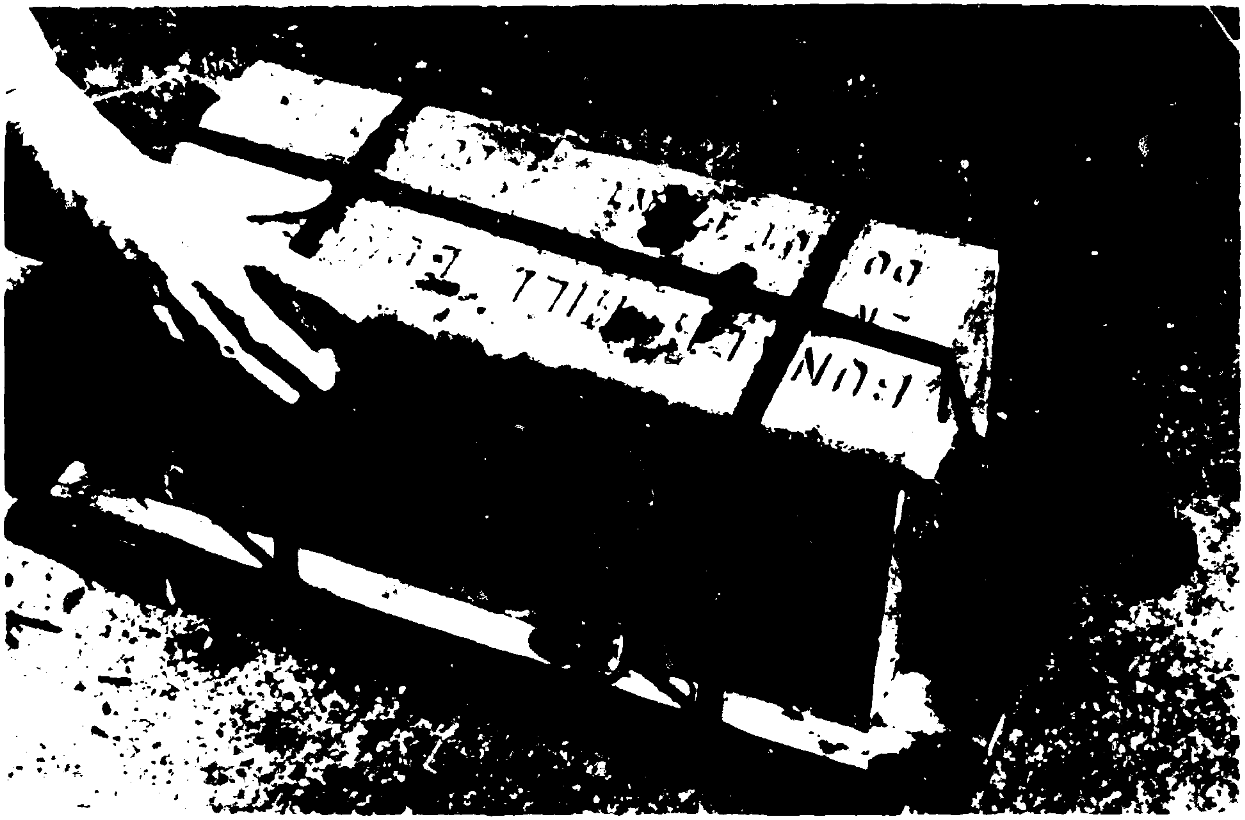

Figure 2. Specially-cast zinc anodes for installation on ground legs.

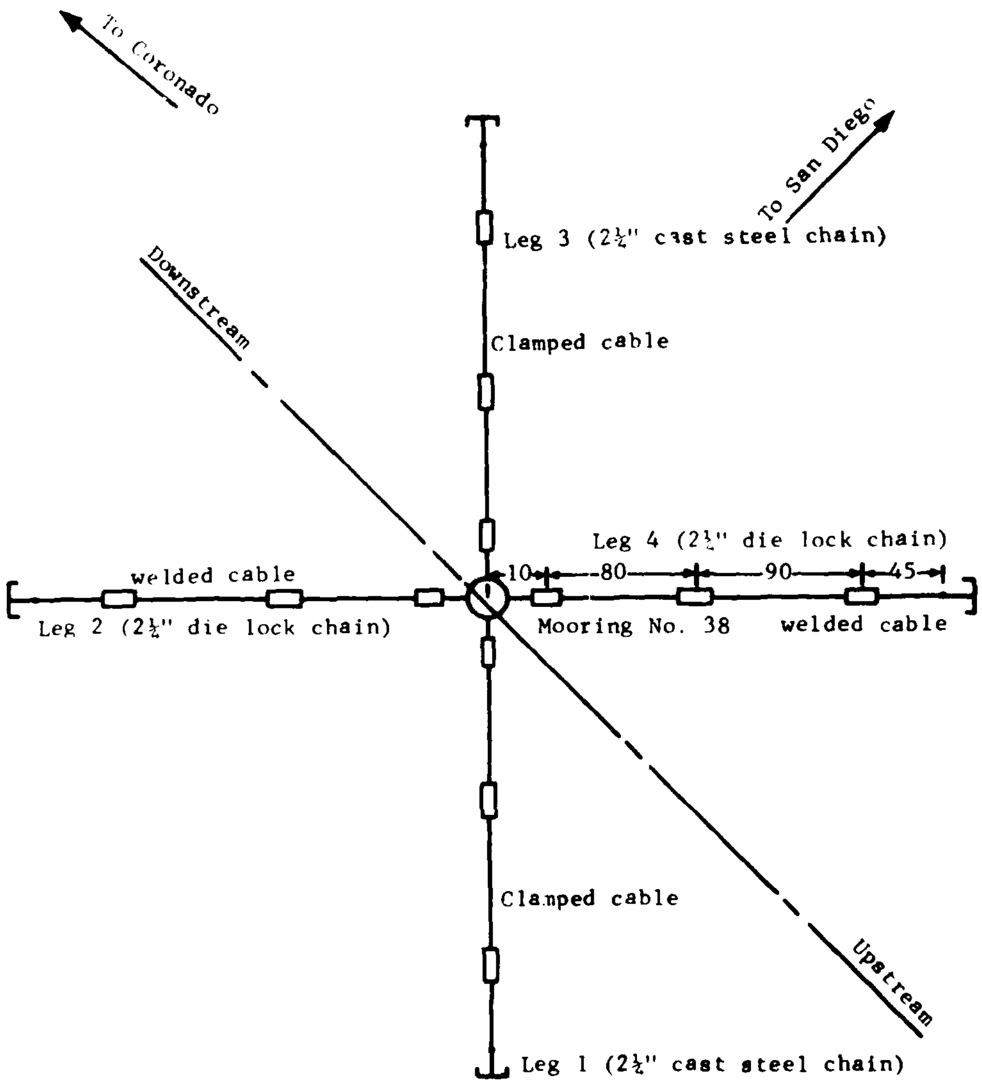

Figure 3. Lay-out of cathodically pr   ected mooring showing methods of cable attachment.

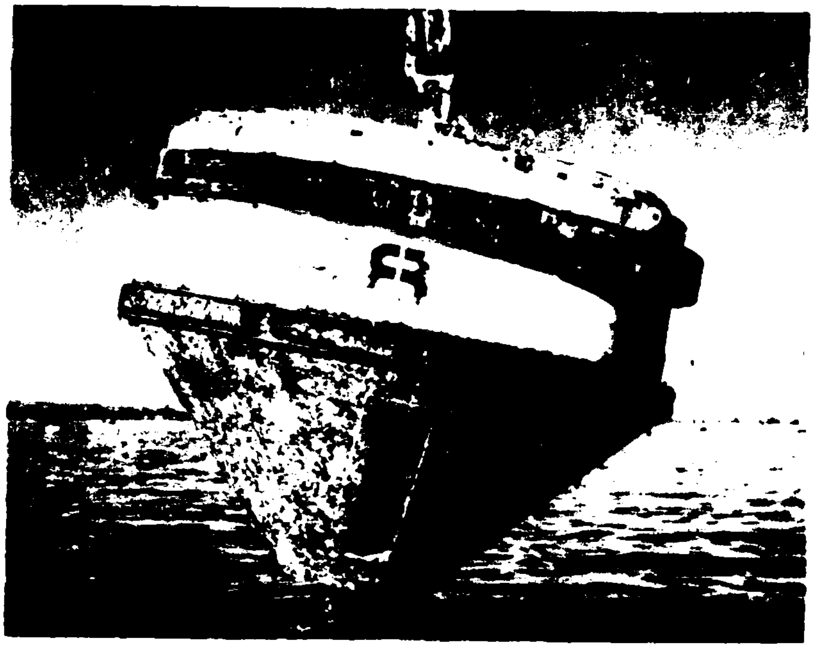

Figure 4. Cathodically protected buoy after removal of fouling.

Figure 5. Engineer measuring diameter of riser-chain link.

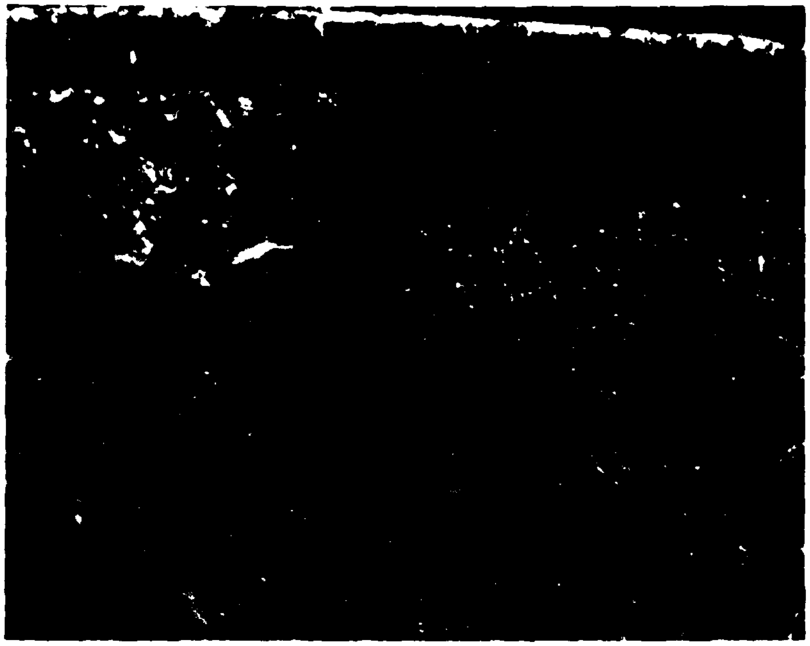

Figure 6. Square of bare steel on underwater portion of cathodically protected buoy.

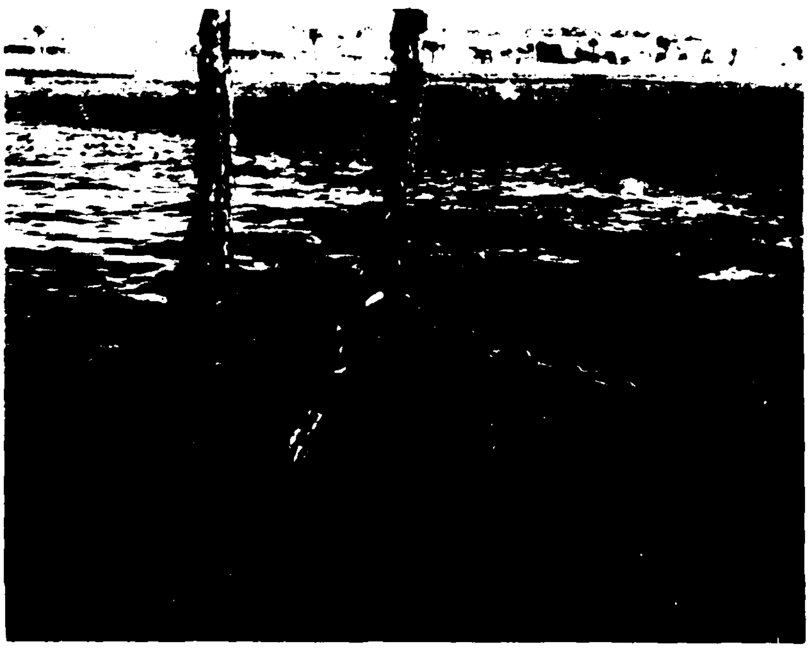

Figure 7. Corroded ground ring assembly of mooring without cathodic protection.

Table 1. Partial Profile of Cathodically Protected Mooring Four Months After Relocation

Potential in Millivolts[1/]				
Riser-Chain	Leg 1	Leg 2	Leg 3	Leg 4[8/]
-960[2/]	-905[4/]	-905[4/]	-905[4/]	-905[4/]
-940	-905	-900	-910	-980
-940	-950[3/]	-960[3/]	-970[3/]	-910
-1005[3/]	-900	-910	-920	-910
-905[4/]	-900	-910	-920	-920
	-900	-915	-920	-920
	-900[6/]	-915	-920	-920
		-920	-920	-920
		-920	-920	-920
		-960[3/]	-975[3/]	-925
		-910	-910	-925
		-910	-910	-920
		-900	-920	-920
		-900	-920	-920
		-900	-915	-920
		-880	-915	-920
		-960[3,7/]	-960[4/]	-980[4/]
			-905	-[illegible]30
			-905	-925
			-900	-920
			-880[5/]	-660[5/]

(Cont'd)

Table 1. (Cont'd)

1/ Potential recorded about every 10 to 20 feet.

2/ At buoy.

3/ At link on which anode was cast.

4/ At ground ring.

5/ At anchor.

6/ Leg lost in mud; unable to repeat measurement because of engine failure.

7/ Measurements discontinued because of engine failure.

8/ Two anodes in the mud were not located.

Table 2. Potential Profile of Cathodically Protected Mooring Nine Months After Relocation

Potential in Millivolts[1/]				
Riser-Chain	Leg 1	Leg 2	Leg 3	Leg 4
-940[2/]	-890[4/]	-890[4/]	-890[4/]	-890[4/]
-920	-890	-890	-890	-890
-920	-985[3/]	-990[3/]	-980[3/]	-990[3/]
-970[3/]	-930	-920	-930	-920
-890[4/]	-930	-910	-920	-920
	-925	-915	-930	-920
	-920	-910	-930	-930
	-920	-910	-935	-930
	-930	-910	-935	-935
	-985[3/]	-970[3/]	-980[3/]	-955
	-930	-910	-940	-935
	-920	-880	-940	-935
	-915	-875	-940	-920
	-915	-875	-935	-930
	-915	-885	-920	-930
	-915	-885	-940	-940
	-990[3/]	-970[3/]	-1020[3/]	-1000[3/]
	-910	-885	-945	-930
	-910	-970	-940	-930
	-900	-870	-940	-930
	-870[5/]	-720[5/]	-665[5/]	-645[5/]

(Cont'd)

Table 2. (Cont'd)

1/ Potentials recorded about every 10 to 20 feet.

2/ At buoy.

3/ At link on which anode was cast.

4/ At ground ring.

5/ At anchor.

Table 3. Potential Profile of Cathodically Protected Mooring Fifteen Months After Relocation

Potential in Millivolts[1/]				
Riser-Chain	Leg 1	Leg 2	Leg 3	Leg 4
-955[2/]	-880[4/]	-880[4/]	-880[4/]	-880[4/]
-980	-870	-880	-880	-890
-980	-995[3/]	-980[3/]	-985[3/]	-990[3/]
-980[3/]	-920	-920	-930	-920
-880[4/]	-910	-920	-925	-915
	-900	-920	-920	-915
	-895	-920	-920	-915
	-900	-920	-910	-920
	-905	-930	-920	-925
	-970[3/]	-980[3/]	-990[3/]	-965[3/]
	-905	-925	-910	-920
	-895	-920	-920	-930
	-900	-920	-905	-930
	-895	-920	-915	-930
	-895	-920	-920	-930
	-900	-920	-920	-930
	-960[3/]	-970[3/]	-985[3/]	-995[3/]
	-900	-920	-905	-930
	-895	-910	-895	-935
	-885	-905	-885	-910
	-690[5/]	-720[5/]	-770[5/]	-655[5/]

(Cont'd)

Table 3. (Cont'd)

1/ Potentials recorded about every 10 to 20 feet.

2/ At buoy.

3/ At link on which anode was cast.

4/ At ground ring.

5/ At anchor.

Appendix

ANALYSIS OF COSTS OF REHABILITATING FLEET MOORINGS

Costs of rehabilitating fleet moorings have been difficult to obtain for analysis. This appendix analyzes data for removal, overhaul, and reinstallation of four fleet moorings by Public Works Center, San Diego These were seven- and eight-legged mooring (BB Ty) with Mark II peg-top riser-chain mooring buoys. A future cost analysis for three- and four-legged moorings will be made should that data become available.

The codes of the work centers performing the various phases of the work are listed in Table A-1. Sandblasting for surface preparation of metal for painting was done by Work Center 540 (General Support Shop). Both rigging and diving services fall under Work Center 728, and this number will refer to rigging service unless otherwise specified.

Tables A-2, A-3, and A-4 list Planning and Estimating Branch estimates for work scheduled for mooring numbers 34, 35, 36, and 37, respectively. The actual man hours spent to accomplish the work were considerably more than estimated. Also, labor costs have since increased by 10% and material costs by 25% (40% for lumber, Work Center 543; 20% for paint, Work Center 525; 10% for sand, Work Center 540; and 10% for other materials). The actual labor costs for each phase of the rehabilitation of the four moorings were not available. The percent of cost for each phase of work from the original estimates (Tables A-2, A-3, and A-4) was used to calculate actual costs for each phase from the total actual hours. This is tabulated in Table A-5 along with corrections for increased labor and material costs. From this table the present (June 1969) average removal, overhaul, and reinstallation costs were calculated to comprise 20, 34, and 43%, respectively, of the total rehabilitation costs.

BUDOCKS INSTRUCTION 11153.4B of 9 April 1965 calls for (1) annual inspection of mooring buoys for damage, deterioration or corrosion, and the physical condition of the ground tackle connected to the buoy, (2) lifting of buoys from the water every 3 years for painting and required repairs, and (3) complete mooring assemblies to be hauled out of the water, inspected, and rehabilitated every 3 years where there are adverse bottom conditions. PWC, San Diego, follows the 3-year program for both buoys and their ground tackle. While conditions in San Diego are severe, conditions may be appreciably worse in tropical environments. In cold areas, factors contributing to corrosion should be appreciably less. The mooring maintenance operations at PWC, San Diego, are considered to be quite efficient, and maintenance costs at other field activities may be appreciably greater. Only a survey of data from other locations could indicate the relative maintenance costs at activities other than PWC, San Diego.

Table A-1. Identification of Work Center Codes

Code	Work Center
210	Engineering Department; Civil Engineering Division
332	Inspection Division
525	Paint Shop
540	General Support Shop
542	Welding Shop
543	Wharf Building Shop
622	Utilities Shop
700	Transportation Department (Equipment Rental)
722	Automotive Operations
724	Heavy Equipment Operations
728	Rigging Service (also Diving Service)
772	Heavy Equipment Maintenance

Table A-2. Fleet Mooring No. 3, Estimated Costs

Removal of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
700	0	0	0	451	451
722	3	0	0	0	20
724	15	108	0	0	108
728	108	789	0	0	789
772	12	99	0	0	99
Total	138	1,016	0	451	1,467

Overhaul of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
332	10	76	0	0	76
525	20	155	235	0	390
540	[illegible]	349	145	0	494
542	8	63	0	0	63
543	60	[illegible]	248	0	727
700	0	0	0	170	170
724	24	173	0	0	173
728	24	175	0	0	175
Total	198	1,470	628	170	2,268

Reinstallation of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
210	(Info only)	0	0	0	0
700	0	0	0	751	751
722	3	20	0	0	20
724	21	151	0	0	151
728 (Divers)	63	672	0	0	672
728 (Riggers)	140	1,023	10	0	1,033
772	17	141	0	0	141
Total	244	2,007	10	751	2,768

(Cont'd)

Table A-2. (Cont'd)

Total Work

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Labor Costs	$ Total
210	(Info only)	0	0	0	0
332	10	76	0	0	76
525	20	155	235	0	390
540	52	349	145	0	494
542	8	63	0	0	63
543	60	479	248	0	727
700	0	0	0	1,372	1,372
722	6	40	0	0	40
724	60	432	0	0	432
728(Divers)	63	672	0	0	672
728(Riggers)	272	1,987	10	0	1,997
772	29	240	0	0	240
Total	580	4,493	638	1,372	6,503

Table A-3. Fleet Mooring Nos. 35 and 36 Estimated Costs*

Removal of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
700	0	0	0	446	446
722	4	20	0	0	27
724	20	144	0	0	144
728	108	789	0	0	789
772	12	99	0	0	99
Total	144	1,059	0	446	1,505

Overhaul of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
332	8	61	0	0	61
525	20	155	352	0	507
540	56	383	163	0	546
542	8	63	92	0	155
543	52	415	125	0	540
700	0	0	0	149	149
724	24	173	0	0	173
728	24	175	0	0	175
Total	192	1,425	732	149	2,306

Reinstallation of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
210	(Info only)	0	0	0	0
700	0	0	0	964	964
722	4	27	0	0	27
724	24	173	0	0	173
728(Divers)	72	768	0	0	768
728(Riggers)	212	1,550	0	0	1,550
772	24	199	0	0	199
Total	336	2,717	0	964	3,682

* Cost estimates for both fleet moorings were identical.

(Cont'd)

Table A-3. (Cont'd)

Telephone Removal and Installation

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
622(Removal)	8	63	0	0	63
622(Installation)	8	63	216	0	279
Total	16	126	216	0	342

Total Work

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
210	(Info Only)	0	0	0	0
332	8	61	0	0	61
525	20	155	352	0	507
540	56	383	163	0	546
542	8	63	92	0	155
543	52	415	125	0	540
622	16	126	216	0	342
700	0	0	0	1,559	1,559
722	8	54	0	0	54
724	68	490	0	0	490
728(Divers)	344	2,514	0	0	2,514
728(Riggers)	72	768	0	0	768
772	36	298	0	0	298
Total	688	5,327	948	1,599	7,834

Table A-4. Fleet Mooring No. 37 Estimated Costs

Removal of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
700	0	0	0	445	445
722	3	20	0	0	20
724	15	108	0	0	108
728	108	790	0	0	790
772	12	99	0	0	99
Total	138	1,017	0	445	1,462

Overhaul of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
332	10	76	0	0	76
525	20	155	243	0	398
540	52	356	145	0	501
542	8	63	0	0	63
543	60	479	248	0	727
700	0	0	0	138	138
724	24	173	0	0	173
728	24	175	0	0	175
Total	198	1,477	636	138	2,251

Reinstallation of Mooring

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
210	(Info only)	0	0	0	0
700	0	0	0	789	789
722	3	20	0	0	20
724	21	151	0	0	151
728(Divers)	63	672	0	0	672
728(Riggers)	140	1,023	24	0	1,047
772	17	141	0	0	141
Total	244	2,007	24	789	2,820

(Cont'd)

Table A-4. (Cont'd)

Total Work

Work Center	Man Hours	$ Labor Costs	$ Materials Costs	$ Other Costs	$ Total
210	(Info only)	0	0	0	0
332	10	76	0	0	76
525	20	155	243	0	398
540	52	356	145	0	501
542	8	63	0	0	63
543	60	479	248	0	727
700	0	0	0	1,372	1,372
722	6	40	0	0	40
724	60	432	0	0	432
728(Divers)	63	672	0	0	672
728(Riggers)	272	1,988	24	0	2,012
772	29	240	0	0	240
Total	580	4,501	660	1,372	6,533

Table A-5. Calculated [illegible] Costs and Projected Present (June 1969) Costs for Moorings Maintenance

Phase of Work	Mooring Number	Calculated Man Hours	Labor Costs ($)	Materials Costs ($)	Other Costs ($)	Total Actual Costs ($)	10% of Labor Costs ($)	25% of Materials Costs ($)	Total Present Costs ($)
Removal (20% of total present costs)	34	152	(Man Hours X 7.36)	0	451				
	35	158		0	446				
	36	158		0	446				
	37	152		0	445				
	Average	156	1,148	0	447	1,595	115	0	1,710
Overhaul (34% of total present costs)	34	218	(Man Hours X 7.43)	750	170				
	35	211		850	149				
	36	211		850	149				
	37	218		750	138				
	Average	215	1,597	800	152	2,549	160	200	2,909
Reinstallation (43% of total present costs)	34	268	(Man Hours X 8.14)	15	751				
	35	369		0	964				
	36	369		0	964				
	37	268		30	789				
	Average	319	2,597	11	867	3,475	260	3	3,738
Telephones (3% of total present costs)	34	0	(Man Hours X 7.88)	0	0				
	35	18		270	0				
	36	18		270	0				
	37	0		0	0				
	Average	9	71	135	0	206	7	34	247
Total	34	638		765	1,372				
	35	756		1,120	1,559				
	36	756		1,120	1,559				
	37	638		780	1,372				
	Average	697	5,413	946	1,466	7,825	542	237	8,604

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13. ABSTRACT

An investigation was continued into the cathodic protection of fleet moorings, both the underwater portion of the buoy and the ground tackle. Sacrificial zinc anodes used on the ground tackle were specially cast on steel chain links so that they became an integral part of the ground tackle. The tight riser chain secured to the peg-top buoy had the required electrical continuity between chain links to permit the flow of current, but it was necessary to use a steel cable woven through the links of each of the ground legs and periodically joined to them to impart complete continuity between links.

The cathodic protection system was shown to impart complete protection from corrosion to both the underwater portion of the buoy and to the ground legs, whether the latter were on either a sandy or a muddy bottom. It is estimated that this system can provide such protection for a total of at least five years.( )

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Buoys						
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Mooring						

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